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Site selection for mollusc culture

CONTENTS

NETWORK OF AQUACULTURE CENTRES IN ASIA
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SITE SELECTION FOR MOLLUSC CULTURE[1]

by

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INTRODUCTION

A great variety of mollusc species are of commercial importance throughout the world. Apart from molluscs harvested from natural fisheries, a large number is cultured. Figure 1 shows total world landings, both capture and culture, of molluscs from 1980 (3,603,426 MT) to 1986 (4,524,929 MT) with an average annual growth rate of about 3.95% (FAO, 1988). In the mollusc fishery sector the landings from aquaculture activities are high. Figure 2 shows the 1985 mollusc landings from both capture and culture fisheries. Over 2.8 million metric tons of molluscs were cultured in 1985 which accounted for over 65.5% of the year's total production (4,399,371 MT), obviously indicating the importance of aquaculture activities with regard to this resource group.

The major division among these molluscs should be between the two classes Bivalvia and Gastropoda. The former class includes organisms like oysters, mussels, cockles, and clams whereas the latter includes organisms such as abalones and top shells (Fig. 3). Species belonging to the above groups have evolved in such a way that almost all kinds of marine habitats have been exploited. However, within these habitats there are often one or more environmental factors responsible for the dispersion of a particular species over given geographical areas. These limiting parameters are key factors when sites are selected for the culture of a particular species.

As mentioned earlier the world mollusc output production has been steadily increasing within the last few years, however many major producing countries are now facing a number of problems, particularly limited areas available and competition with other common users. For the industry to further expand, it is essential that proper sites are selected whenever a commercial mollusc culture venture, either large or small, is being planned.

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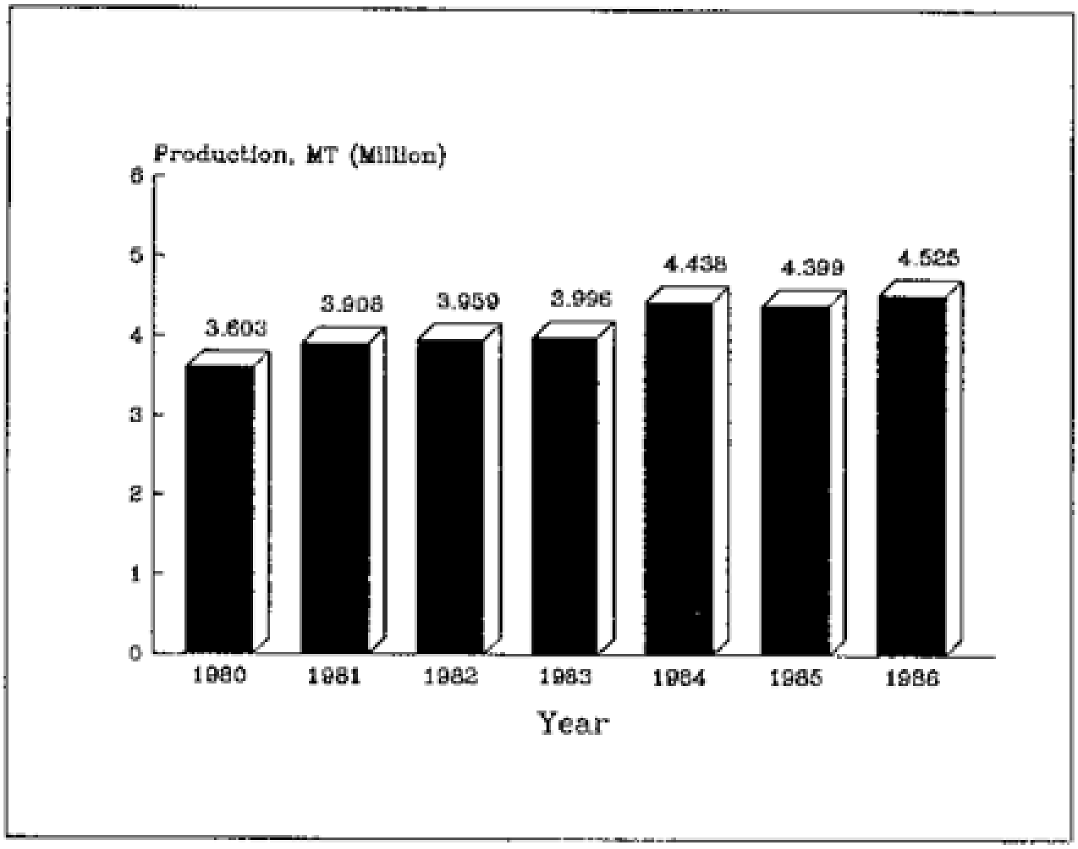


Figure 1. World mollusc landings from 1980 to 1986.

The success of mollusc seafarming depends to a great extent on the proper selection of culture sites. In selecting a site for mollusc culture, considerations should be carefully given to a number of factors which can be grouped under primary and secondary factors (Fig. 4). Physical, ecological and biological factors (primary factors) are of prime importance in the selection of suitable culture sites, while factors such as risk and economics usually follow in terms of importance. It is important to understand that if the primary factors are not fully satisfied, the particular site under consideration should be discarded whether or not all secondary factors are satisfied. Assuming that the criteria are satisfied for all primary and secondary factors, a system of assigning weights for each criteria satisfied can be deviced so to determine the degree of site suitability i.e. from barely suitable to highly suitable, etc.

Figure 5 shows a list of primary and secondary factors which need to be considered when a particular site is being evaluated as a suitable culture site for a specific mollusc species. All of these factors are considered individually throughout the paper. As summarized in Figure 6 the selection of a culture site is initially determined on what molluscan species is intended to be cultured and consequently on the tolerance range of the above species to a number of environmental parameters (e.g. salinity tolerance range). Furthermore the site will have to be suitable to the culture method or system intended to be practiced.

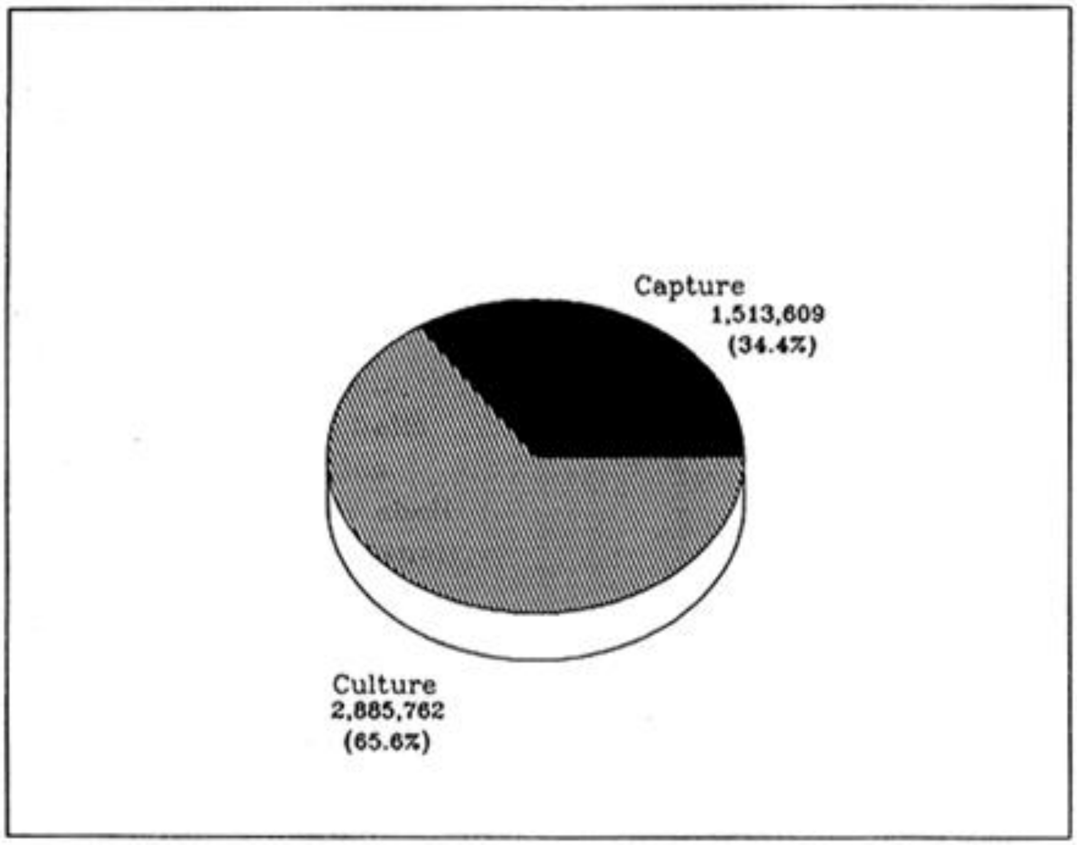


Figure 2. World mollusc landings from capture and culture fisheries in 1985.

For example suitable sites where bottom culture can be practiced due to favorable environmental conditions may not be suitable for practicing the long-line method as the water depth may not be clear enough to justify such technique; or it maybe impossible to establish it due to the fact that the sea bottom becomes exposed during low tide. Practically each environment determines what culture method can be established in that particular area. Finally socio-economic and practicability factors will then have to be considered. The site should be easily accessible, easy to guard, and should not be in competition with other users. The type of culture method to be established is often closely dependent on the financial resource available, as it is obvious that the raft method is more capital intensive than pole culture.

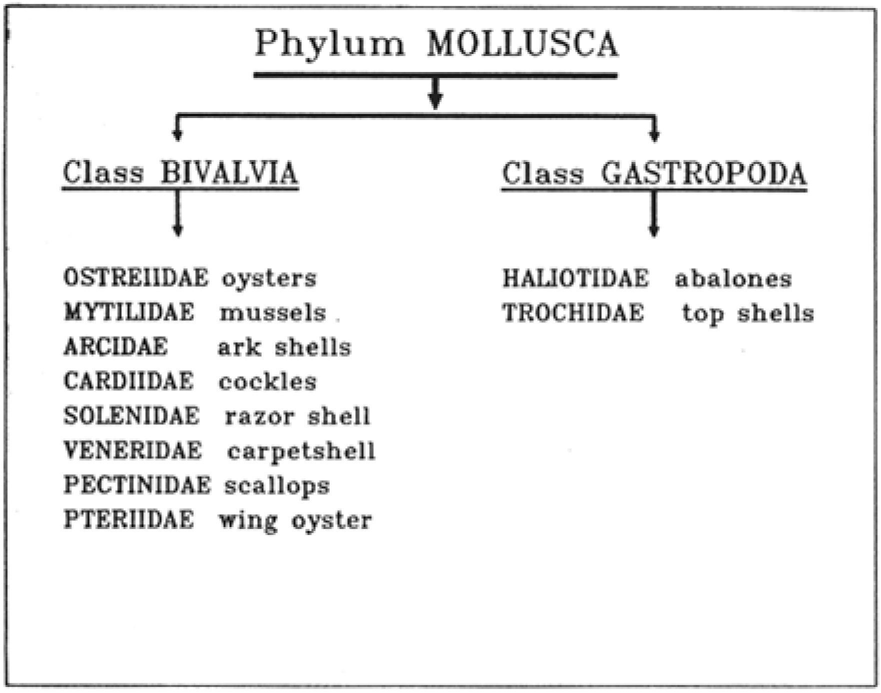


Figure 3. Numerous molluscan species belonging to the Bivalvia and Gastropoda classes are of great commercial importance as indicated.

PRIMARY FACTORS

Area location

Locating the culture site would vary according to species and culture system. For strictly bottom dwellers such as the blood cockle Anadara granosa, the ark shell Arca broughtonii and the carpet shell Venerupis japonica the culture grounds should be located in protected areas where strong winds (eg. monsoon) do not prevail seriously over the area. Deposition of mud and fast siltation rates are often related to water turbulence partly induced by wind action. Although cockles and clams can actively move within their substrate, heavy mud deposition can cause serious mortality either by physically trapping the organism below the soil/water interface or by raising turbidity to a level where filtering activity is completely hindered. Siltation is a major constraint to oyster culture in Peninsular Malaysia, particularly in the Muar River in the southern State of Johore. For species which can be cultured by using different systems such as pole, rack or hanging, the location of a suitable area will depend on the culture system intended to be established. Oyster long-line culture as practiced in the Republic of Korea (ROK) allows the exploitation of areas which would be otherwise unsuitable for other bivalve culture systems (Fig. 7). Long-lines can withstand relatively strong wind and wave action due to the flexibility of the system itself (Fig. 8). The only limitation of the above offshore system is the depth of the water column which will determine the length of the rens.

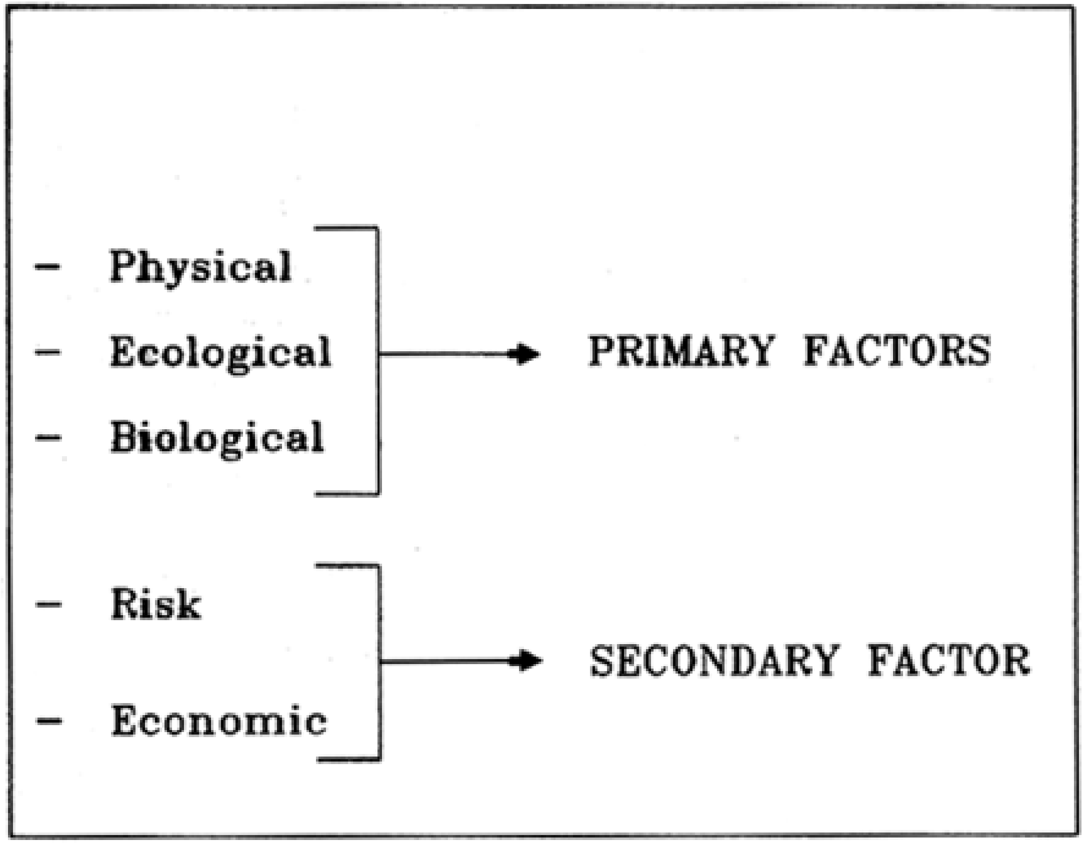


Figure 4. A number of factors (primary and secondary) play an important role in the selection of proper sites for mollusc culture activities.

The length of the rens or of any other hanging structures used like lantern nets, pearl nets, etc. usually determine whether a long-line or raft structure would be economical to establish. The length of these culture units is usually limited to the upper water layers which abound in phytoplankton cells, however a minimum length is necessary in order to economically justify the initial investment and running cost of the above facilities. In ROK one long-line unit is usually 100 metres long and consists of about 51 polyethylene floats connected to one another by a 15 mm diameter polyurethane rope. From this rope the oyster strings (rens) measuring between 5 to 7 meters are suspended at intervals of 1 metre.

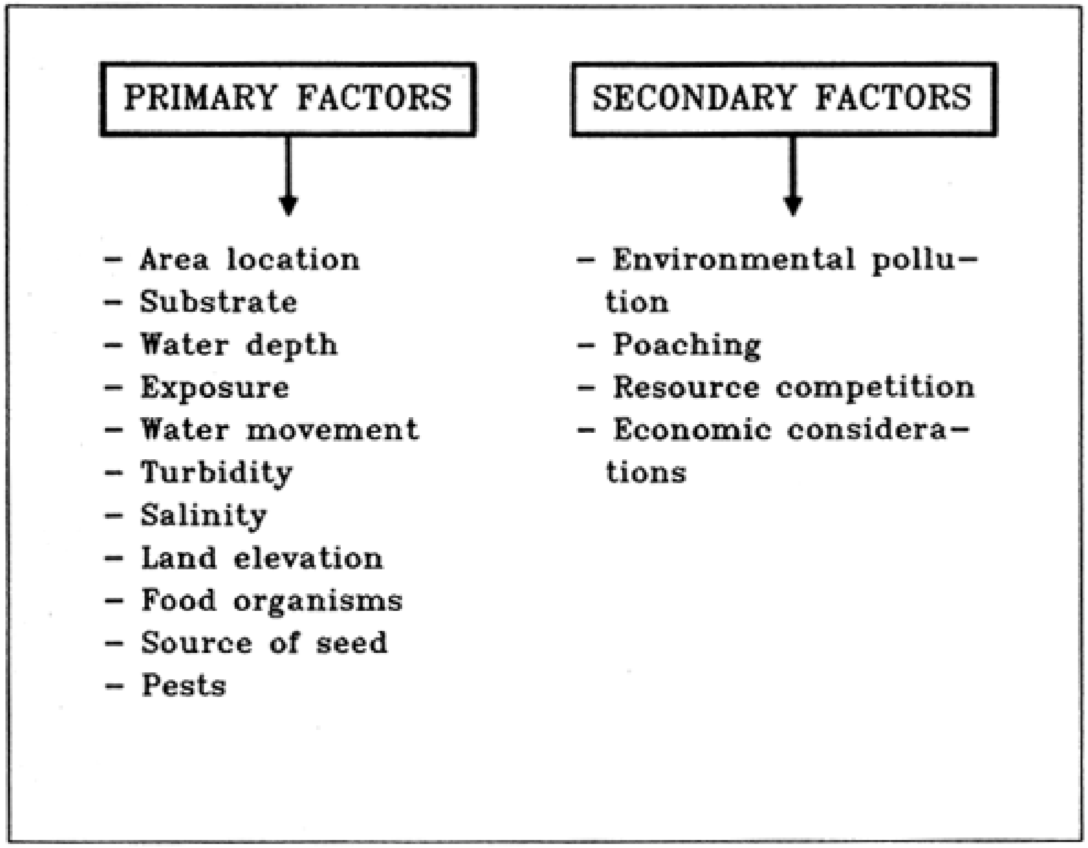


Figure 5. List of primary and secondary factors which need consideration when selecting sites for mollusc culture.

Substrate

Substrate composition and stability is a major environmental parameter to be considered during the selection of a culture site suitable for benthic species such as cockles and clams or where bottom culture is intended to be carried out. Substrate composition will determine the suitability of an area for a particular species.

Cockles are usually found on muddy or silty-clay bottoms, with the highest population densities found on soft intertidal mud flats bordering mangrove swamp forests (Pathansali, 1966).

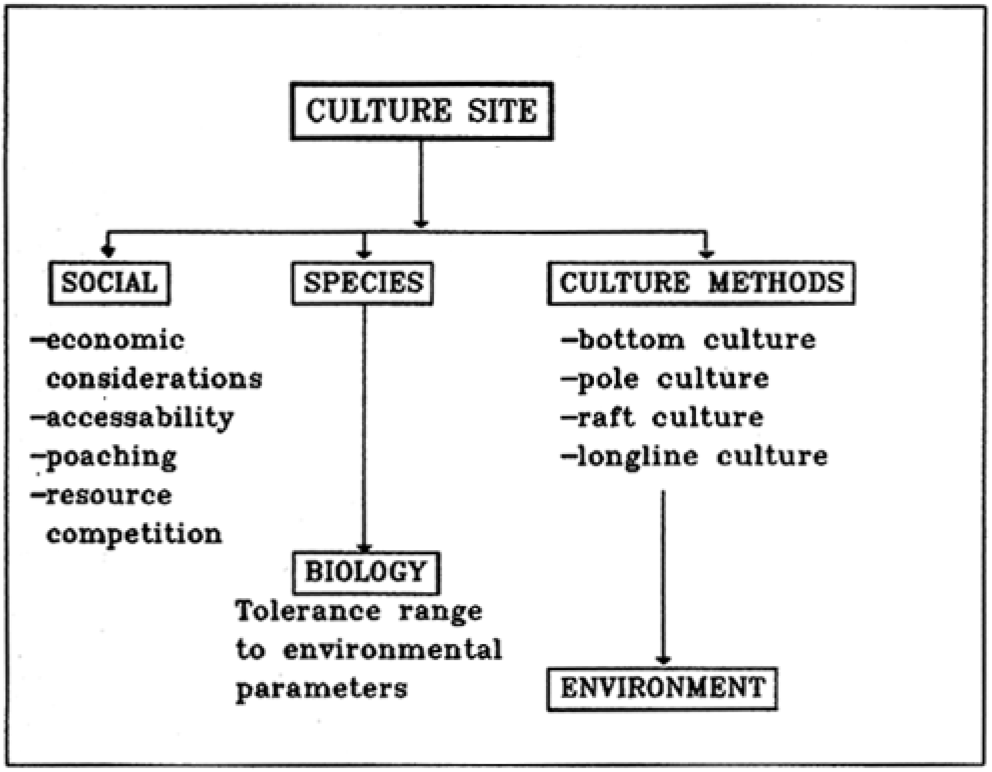


Figure 6. Overall factors which need to be considered when selecting potential culture sites.

Observations on cockle spatfall showed that they settle mainly on fine, soft, blackish mud. In Penang Island, Malaysia the well known Bagan Jermal bed adjoins areas of sand, sandy-mud and stiff black mud with sand, shell and plant debris. In this area spatfall has taken place every year with the greatest concentration always on fine soft mud (Fig. 9). Broom (1982a) studied two populations of A. granosa at two locations on the coast of Selangor, Malaysia, and found that the water content of the substrate was between 55 to 65% and the proportion of particles less than 53 micron in diameter was 80–90%. Other cockle species tend to occupy muddy substrates. Cahn (1951) reported that A. granosa bisenensis is typically an inhabitant of muddy substrates and Kanno (1966) showed that in Sendai Bay, Japan, large dense populations of A. broughtonii exist only in those areas where silt is the dominant substrate.

Not all species of Anadara are associated with muddy substrates. In the Indo-Pacific region, Anadara antiquata is usually found in sublittoral areas inhabiting rocky crevices and attached to rocks and stones by a slender byssus. Anadara anomala is also found sublittorally, but in sandy substrates. Anadara inequivalvis is found intertidally in sandy areas (Lim, 1966).

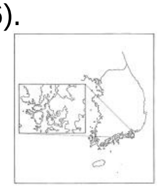
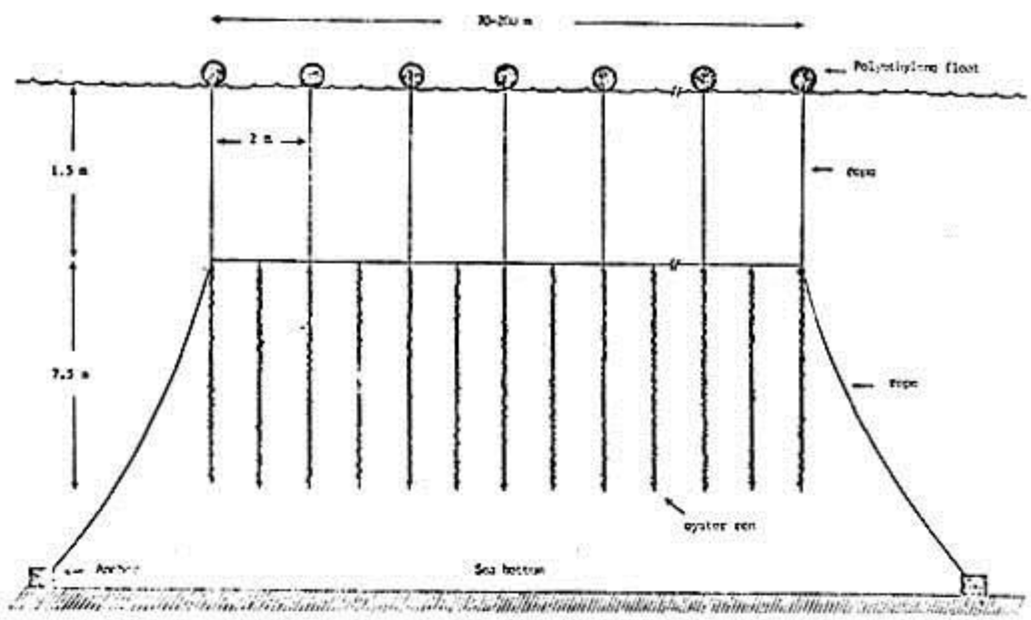
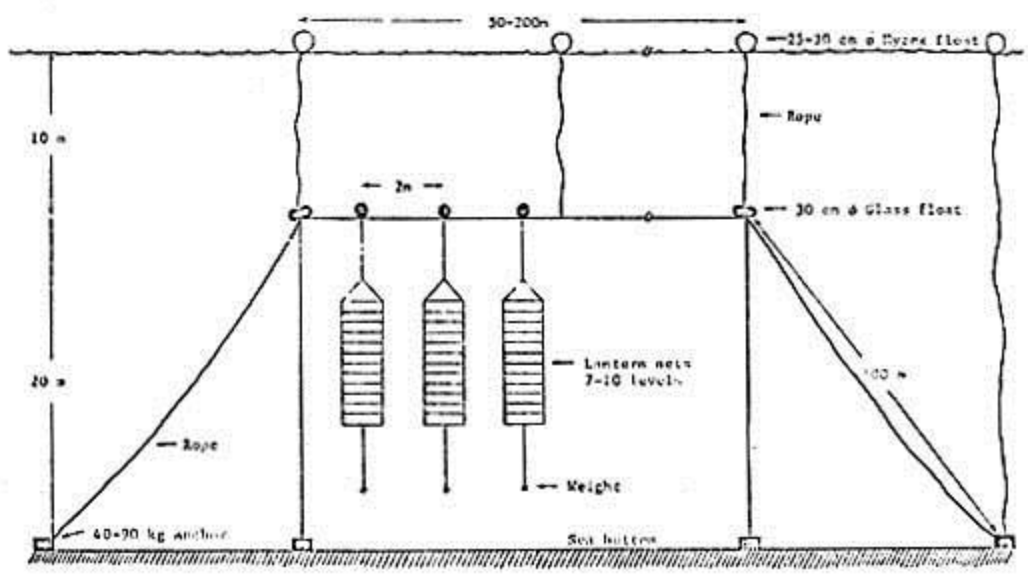


Figure 7. Map of the Republic of Korea (ROK) and coastline details of Chungmu area where oyster long-line culture is extensively practiced.



Polyethylene float
2 m
1.5 m
Rope
7.5 m
Rope
oyster ren
Sea bottom

A



30-200m
Rope
10 m
2m
30 cm ø Glass float
Lantern nets
7-10 levels
20 m
Rope
Weight
Sea bottom

B

Figure 8. Oyster (A) and scallop (B) long-line culture as practiced in ROK and Japan respectively.

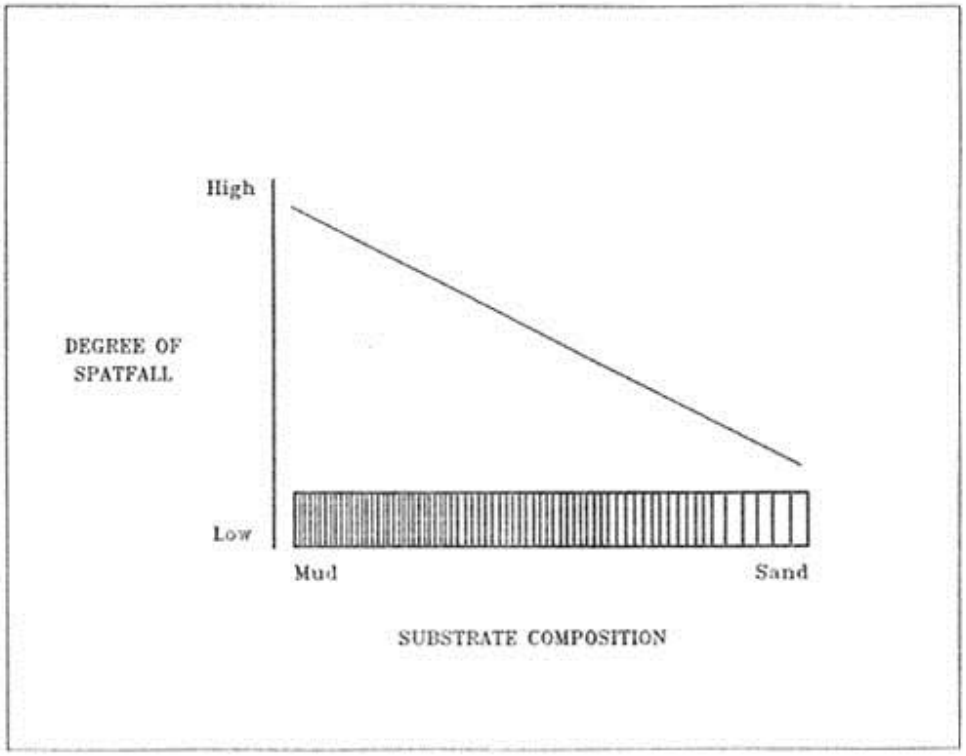


Figure 9. Degree of cockle spatfall in relation to substrate composition.

Oyster bottom culture is limited to areas where the sea floor is firm enough to support some kind of cultch and where siltation is not excessive. This traditional culture method, although not as productive as other culture systems such as the raft method, is sometimes the only system that can be adopted either due to a number of unfavorable environmental conditions or limited funds. This method is in fact the most inexpensive as it relies exclusively on the availability of stones, empty oyster shells or similar materials on which the oysters settle and grow.

This method is widely adopted in many areas around the world. In Thailand rocks are usually piled in groups of 5–10 and spread in rows approximately 50 cm apart in each direction. This technique is used in areas with hard, sandy or sandy-mud bottoms firm enough to support the rocks, however bamboo mats or platforms are commonly used in soft bottom areas to prevent the rock from sinking (Lovatelli, 1988). The use of bamboo mat adds to the initial investment cost and needs to be replaced quite frequently. If bottom culture is the only possibility, substrate nature in terms of firmness needs to be carefully examined in order to carry out a correct cost/benefit analysis.

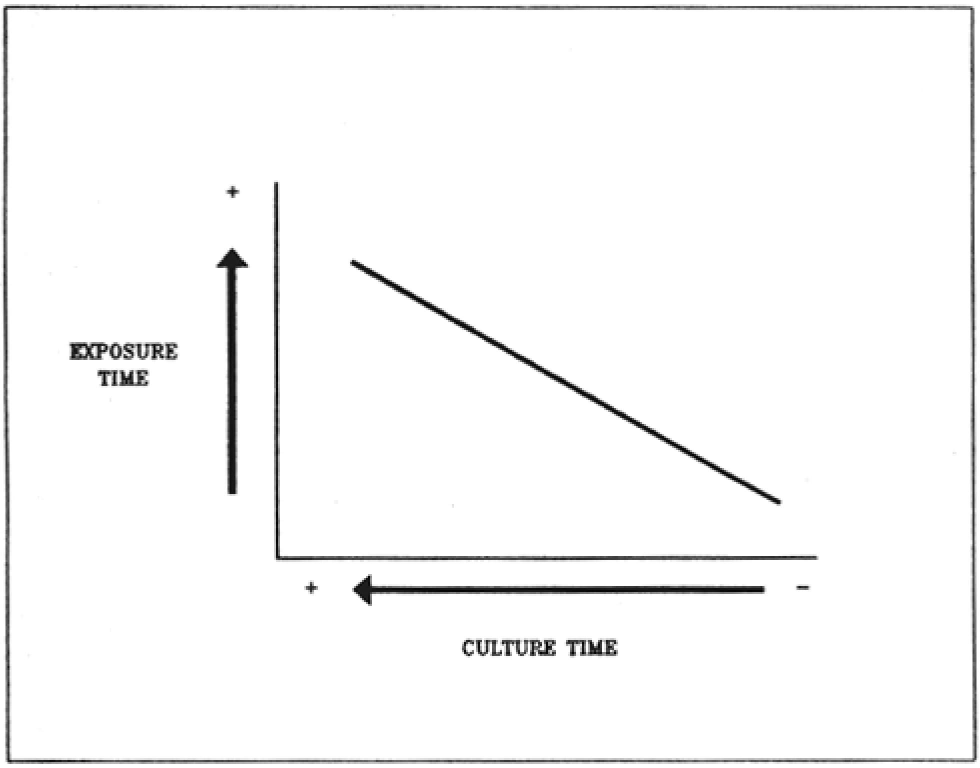


Figure 10. Bivalve culture time in relation to exposure time.

Water depth

Water depth is not usually a limiting factor in mollusc culture, however it will determine what culture method can be used. Probably the most important aspect with regard to water depth is to avoid long exposure periods during the extreme low water spring tides when benthic molluscs such as cockles and clams are cultured. Long exposure periods increase the culture period due mainly to the fact that during these periods the molluscs burrow into the substrate and stop feeding. However one advantage may be during the harvesting phase particularly where it is carried out manually.

With cockle culture, where planting and harvesting is carried out from a vessel, the culture area should have a water depth of about 1 to 2 m mean tide level.
The Manila clam, Tapes semidecussatus is a highly valued species in Europe, particularly in Spain, France and Italy. They are cultured in mud flats in enclosed bays, lagoons, man-made ponds and areas bordering estuaries. Preparation of the ground is necessary to enable the clams to dig themselves in. Usually, a protective fence is built around the culture site. Removal of predators, especially crabs, is necessary and carried out periodically. Harvesting is generally done manually although harvesting and cleaning machines have been developed. All these activities are usually carried out during the exposure period. Therefore, sites which are selected for this kind of culture generally become exposed for short periods during the tidal cycle.

With regard to mussel and oyster culture the water depth depends on the culture method and it can be in the range of 1–15 m mean tide level. In areas where the mean tide level is usually less than 1.5 m, bottom culture on rocks or other materials can be practiced. For raft and hanging method, the water depth can be a limiting factor as usually a minimum water column height is essential during the low water spring tides. In the above two culture methods, the hanging rens should never touch the bottom mainly to prevent predators from reaching the bivalves, avoid exposing the molluscs to high water turbidity near the seabed, and avoid losing the bivalves at the end of the rens as a result of their friction with the ground. Culture ropes should be above the sea floor at least 1 m during extreme low water spring tides (Fig. 7).

Exposure

Marine molluscs are unable to function when removed from their water medium and long exposure periods usually lead to death. Exposure is one of the major environmental condition which influences the growth and mortality of marine molluscs. Both growth and mortality rate vary according to shore elevation. Growth performance of a mollusc located at higher levels is usually lower compared to one located at lower levels, due to prolonged exposure periods and subsequently reduced feeding time (Fig. 10).

Exposure to sun is one of the physical parameters which need to be taken into account when selecting a potential culture ground in shallow coastal areas. In raft or long-line culture, exposure is not a problem as the cultured organisms are always below the water surface. Exposure, however has a number of advantages, particularly with regard to the mortality rate. There is in fact evidence that mortality increases markedly with depth due to a greater degree of predation at the lower levels, presumably as a result of longer access time of predators in the culture grounds. It has been suggested that optimum sites for culturing benthic bivalves are areas which become exposed for periods lasting 2–3 hours. A further example where limited exposure is an advantage can be clearly seen in the mussel culture industry in the venetian lagoon, Italy. Mussel (Mytilus edulis) is extensively cultured by using the rack hanging method. During late spring and summer month the suspended ropes bearing the mussels (known as “pergolari”) become heavily encrusted with fouling organisms, such as seasquirts and seaweeds. The presence of these organisms is undesirable because they compete for food and space and critically increase the weight of each hanging unit.

There is, therefore, a need to remove these fouling organisms. This laborious process, however, is not required in this particular site, as the adequate exposure time of the mussel ropes causes all encrusted organisms to dry up. In other areas such as Taranto, in the south of Italy, mussel aquaculturists have to routinely suspend the mussel ropes and remove the fouling organisms manually (Bussani, 1983). This process is time consuming and labour intensive. Labour effort and growth period are therefore related to exposure.

Water movement

Bivalve culture sites should not be in the vicinity of strong currents particularly where bottom culture is practiced as strong currents usually generate high turbidity and high siltation rates. However, moderate currents are needed to provide adequate food supply. Currents of 0.02–0.1 m/sec have been reported to be suitable for cockle cultures, while stronger currents are usually required for the hanging method due to the intensive culture nature of this method (Tiensongrusmee et al., 1986). In the hanging method, slow water movement usually results in slow growth of the bivalves due to the poor replenishment of food. Slow currents also promote the settling of organic and inorganic particulate materials on the cultured organisms. Potential sites should have a current speed within the range of 0.1–0.3 m/sec.

Turbidity

High turbidity levels due to the presence of finely suspended matter such as clay, sand, and other organic and inorganic particulate materials at the culture site is usually undesirable as it causes ill effects on the bivalves being cultured and often resulting in high mortalities. the presence of suspended materials above a certain level hinders the filtering activity of the bivalve which often remain closed to avoid tissue damage and becoming clogged. In addition, low primary productivity is often the case in sites of high turbidity due to the reduced penetration of sunlight in the water column. As a result poor growth results due to reduced feeding time and limited food available. It has been reported that water containing a high suspended load of more than 400 mg/1 have a lethal effect on the grow-out of mussels (Tiensongrusmee et al., 1986). The maximum suspended load tolerable level varies according to species. A practical method for determining the turbidity level is with the use of the Secchi-disc. Sites having a disc reading less than 15 cm are usually considered unsuitable for bivalve culture.

Salinity

Although most species of molluscs tolerate a certain range of salinity levels, some species tend to be more euryhaline than others. When the salinity value falls below or above the range of a certain species for prolonged periods, high mortalities generally occur. Decrease in salinity levels is usually the major and frequent problem, mainly caused by the influx of large volumes of fresh water from rivers or land runoff during the rainy season. With regard to the blood cockle, Anadara granosa a number of field surveys and laboratory trials have shown that adult specimens function relatively efficiently at salinities above 25 ppt, although young specimens seem to be able to continue normal feeding activity at a lower salinity than older specimens (Broom, 1980). Very young individuals apparently remain active at salinities as low as 18–19 ppt (pathansali, 1963). Although feeding efficiency and activity generally decrease substantially at salinities less than 20 ppt, A. granosa is capable of acclimating to salinities as low as 12 ppt, at least in the short term. These results are consistent with the known distribution of A. granosa in areas where the salinity is usually in the range of 26–31 ppt, but which are subject to large, short-term fluctuations.

Figure 11 shows the salinity range tolerance of some oyster species. Generally, species belonging to the genus Ostrea are found in areas with full strength salinities, whereas those belonging to the genus Crassostrea tend to be more euryhaline.

Bottom slope

The degree of bottom slope is one factor which needs to be considered particularly when the bivalve species is cultured directly on the substrate. Suitable culture beds should have a moderate seaward slope between 5–15 degree. Tookwinas (1985) reported that slopes exceeding 15 degrees often cause cockles to be shifted from their original site due to wind and wave action. On the other hand, if the slope gradient is too little the culture area is often exposed for too long between tides. Where it is too great shifting may occur, as mentioned above, and working conditions are made more difficult as well.

Food organisms

All bivalves are filter-feeders, mainly feeding on a wide range of phytoplankton species. The presence of suitable microalgae species is usually not a problem, however, problems do arise when the availability of food is limited. Bivalve intensively cultured in rafts may be affected by the length of the culture period when food is scarce. In the above example, poor growth is usually the result of poor water movement (ie. low current) rather than food availability.

Another problem related to food organisms are the sudden blooms of certain phytoplankton organisms, usually in coastal waters. This phenomena is known as red tide as the organisms become so dense that the seawater takes on a brown, red or yellow coloration. One major problem related to the red tides is the paralytic shellfish poisoning (PSP) which is the result of eating bivalves that have been harvested during or soon after red tides, in the shellfish culture grounds. In one occasion (June to August 1983) the Philippines experienced a bloom of Pyrodinium a toxic dinoflagellate, resulting in at least 21 deaths and nearly 200 hospitalization from PSP. The red tide occurred in one of the major shellfish growing areas. Unfortunately, it is often difficult to predict if any area is prone to be affected by these toxic blooms, however, during the site selection process, one should ask about the past history of the area. Bivalves affected with red tides are not usually killed, but tend to accumulate toxic substances in their flesh. Depuration studies have shown that those bivalves can be depurated, however the longer depuration time required would make it very uneconomical. Another problem which arises from food organisms are shellfish which are harvested or cultured in estuaries or coastal areas which are used as repositories for untreated domestic sewage. Shellfish from such areas are known to accumulate bacteria and viruses which are pathogenic to man. Major diseases are typhoid and paratyphoid fever, salmonellosis, Vibrio parahaemolyticus infection, cholera, viral Hepatitis type A and viral gastroenteritis. Contaminated bivalves can be made edible by: 1) re-laying or transferring the shellfish to pollution free waters or 2) depuration. These processes are time, labour and cost intensive. Therefore, during site selection it is important to bear in mind that being filter-feeders, they can accumulate pathogenic organisms, toxins as well as heavy metals at levels which can be lethal to humans.

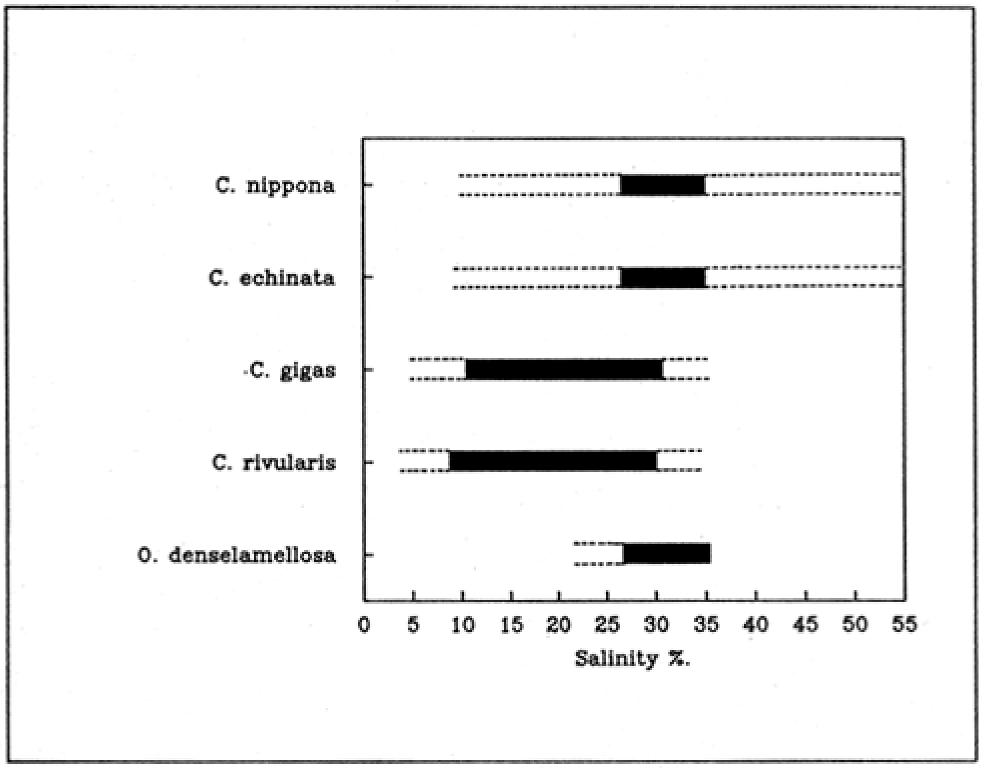


Figure 11. Salinity tolerance range of several oyster species.

Source of seed

The source of seed is one factor which may affect site selection decisions. With regard to endemic species, seed should be available within the vicinity of the selected site. However, if it has to be transported from elsewhere, it should be transported to the farm site within a reasonable time and cost. This factor has to be considered as it will affect the cost and returns analysis. Transportation itself is not only costly, but usually negatively affects the bivalve seed due to abnormal and stressful conditions.

Countries culturing non endemic species are usually faced with the problem of seed supply. One example is the culture of the Manila clam, Tapes semidecussatus in Western Europe, particularly in Italy, France and Spain. Here the aquaculturists rely on hatchery produced seed which command very high prices. (5–6 Pound sterling/1000 specimens measuring 2 mm in length, 1986). The culture of this species is, however, viable as they are efficiently cultured along the Mediterranean coast and command a very high market price. Other cases of scarce seed supply have repeatedly occurred in the Pacific island where suitable culture sites for non endemic bivalve species were located, but eventually confronted with the problem of limited seed supply.

Pests

A great variety of pests affect the on-growing of bivalve species. Major predators are finfish, crustaceans, gastropods, echinoderma and polychaete worms. The sea bream, Sparus aurata, a commercially important species in the Mediterranean countries, feeds mainly on molluscs including lamellibranchs such as mussels, clams and oysters. Similarly, mussels cultured in rafts in New Zealand are mainly predated by two local fish species, the snapper Chrysophrys auratus and the spotty Pseudolabrus celidotus. The blood cockle, Anadara granosa, extensively cultured along the western coast of Peninsular Malaysia as well as in Thailand, are predated by the gastropods Natica maculosa and Thais carinifera. The echinoderm, Asterias amurensis has also been reported to be an important predator of Anadara sp. (Toyo et al., 1978; Anon, 1979, 1980). In one study, experimental areas on the seabed were stocked with Anadara sp. (Anon, 1979). Although at the time of stocking no predators were seen, large numbers of A. amurensis gradually migrated in so that 18 days after stocking they were present at densities up to 11.25/m^2. In a subsequent study divers removed all specimens of A. amurensis from the surrounding area before carrying out experimental stocking (Anon, 1980). However, within two weeks the predator had invaded the plots. Anadara sp. used in these experiments were in the region of 40 mm long indicating that A. amurensis may attack quite large specimens. Serious pest of raft-cultured oysters in tropical waters are spionid polychaetes. Infestations may be extremely heavy, reaching 100%.

The worms may also establish themselves in intertidal oysters. Skeel (1979) found Polydora websteri, P. haswelli, P. hoplura and Boccardia chilensis attacking intertidal cultures of S. commercialis in Australia. The larval worms bore into the oyster shell and upon reaching the inner nacre, the oyster reacts to the irritant by secreting a layer of conchiolin over the site of contact with mantle tissue, forming a “mud blister”. The conchiolin is eventually covered with calcareous material, but mud blisters seriously affect marketability.

Stick culture in the intertidal zone controls Polydora infestation by drying the young stage of the worm before it can bore deep into the shell. If oysters in subtidal trays are placed where there are fast currents or are washed regularly with high pressure spray, infestations can be controlled. Australian oyster farmers dip sticks in hot water to kill excess spat, which also kills the worms. Spionid polychaetes are not true parasites since they do not consume host tissues or fluids but heavy infestation probably stresses the oysters, particularly during or shortly after spawning.

Crabs are another serious pest particularly in bottom culture. The mud crab, Scylla serrata is of major importance in Southeast Asian countries while the common shore crab, Carinus maenas in the Mediterranean and Northern Europe countries.

Control of predation is usually rather expensive mainly because structures have to be raised in order to physically prevent the predators from reaching the bivalves. During site selection it is difficult to determine whether an area would eventually become affected by this problem, however it is good practice to survey the area for potential predators.

SECONDARY FACTORS

Pollution

Pollution of coastal areas has been one of the most delicate subjects in most countries in the past few years. The ever increasing number of urban settlements, the development of intensive agricultural activities and the presence of industries along coastal areas have increased the polluting load of discharge waters flowing into these biologically productive coastal areas. Domestic sewage carries detergents, solids, various toxic substances and pathogens which may directly affect the cultured organisms or indirectly affect man by contaminating the molluscs. Agriculture pollution problems are equally serious typically involving animal wastes, solids, insecticides, herbicides and other pollutants. Industrial activities give off a diverse variety of pollutants. In areas where the effluents are discharged untreated, as in many developing countries, the siting of culture farms near industrial sites could seriously affect production output as well as product quality. Typical examples of heavily polluted areas in Southeast Asia are Jakarta Bay in Indonesia and Manila Bay in the Philippines. Due to the pollution problems and numerous health incidences related to the consumption of molluscs reared in these sites, the mollusc culture enterprises in these bays have suffered severe losses particularly in terms of reduced market demand. When pollution problems are considered, it is prudent to ensure that culture investments will not be affected by pollutants. In this connection, the location of pollution sources and the pattern of seawater transport should be carefully considered.

Poaching

The problem of poaching and sabotage is common in fisheries and perhaps more so in aquaculture. The only effective solution to this problem is constant surveillance of the culture ground. Living in the vicinity of the culture site is obviously an optimum situation for keeping constant watch over the stock and facilities. Unfortunately, this situation is not common as most farmers live in a settlement (villages) located away from these grounds. The common practice in Southeast Asia is to construct small guard houses at the culture site, large enough to accommodate one or two people. This adds to the production cost, however, it is the only effective way to prevent poaching, particularly in developing countries.

Resource competition

In stocking suitable culture sites, potential problems may arise from the conflicting activities of the common users of the sea. These should be taken into account. The proximity of the culture sites to navigation channels, recreational activities and industrial activities may expose the farm to a series of problems generated by the normal activities of the common users. An example is the wave action created by vessels which may have a disturbing or destructive effect on both the cultured organisms and rearing facilities.

Economic considerations

Cost-benefit analysis of a particular bivalve culture system (eg. bottom, raft, long-line, etc.) should also be considered when a given culture site is selected. Culturists interested in commercially growing oysters, as the selected bivalve species, will be confronted with the initial capital investment required to set up the operation. The various culture systems which may be set up to culture the oysters, require different levels of investments depending on the complexity of the system itself.

As shown in Table 1 and 2 the materials necessary to construct an oyster raft or long-line unit respectively are numerous and certainly more capital intensive if compared to the materials required to establish a pole culture plot.

Potential culturists with adequate financial resources may well consider to invest in a more capital intensive system such as the long-line method. If the financial needs do not pose any major problem, the investor will direct his efforts in selecting sites suitable for establishing long-line facilities, therefore excluding all other sites unsuitable for this culture method. By doing so a first step has been taken in site selection.

CONCLUSION

Site selection for any seafarming system is a process by which a number of factors should be carefully analysed prior to the investment itself. The above factors can be arbitrarily divided into two groups: primary and secondary. The factors which are of prime importance are all those biological and ecological factors which will determine whether a particular species will adequately grow in a given site, while secondary factors concentrate on the socio-economic feasibility of the proposed enterprise. The suitability of a site for a particular marine organism will be dependent on the right balance and satisfaction of all major primary and secondary factors.

Table 1. Details of materials for one raft (after Park et. al. 1988).

Material	Specification	Quantity	Remark
Bamboo pole	∅ 10cm, 4.5m long	94 ea.	
Float	Styrofoam, 450 l	13 ea.	
Rope for anchor	Wire rope, ∅ 24mm	70 m	
Anchor	Reinforced concrete, 0.6 M/T	4 ea.	
Hanging string	#13 galvanized wire	3,600 m	9m × 400 strings
Pipe	PVC, ∅ 1cm, 20 cm long	16,000 ea.	40 cultches × 400 strings
Cultch	Oyster shell	16,000 shells	40 cultches × 400 strings

Table 2. Details of materials for one long-line (after Park et. al., 1988)

Material	Specification	Quantity	Remark
Rope	PE rope, ∅ 15mm	100 m	
Rope for anchor	PE rope, ∅ 15mm	60 m	30m for a string
Float	Styrofoam, 60l	51 ea.	At 2m intervals
String	∅ 5 mm, PE coated	142 m	At 70cm intervals
Anchor	Stick or iron	2 ea.	Both sides
Cultch	Oyster shell	2,850 shells	20 cultches × 142 strings
Line for fastening float	PP twist line	255 m	5m × 51 ea.

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